Fraser TSA inventory audit

Introduction

The Ministry of Forests conducts an inventory of each timber supply area (TSA) in British Columbia every 10 to 30 years—using standards and procedures that have been developed by the Resources Inventory Program—with regular updates to reflect changes in the timber volume due to growth and to depletions from harvesting and natural causes.

Fraser TSA is located in the southeast portion of the Vancouver Forest Region, bounded by the US border to the south, the Strait of Georgia to the west, False Creek and Fraser Canyon to the north, and the west gate of Manning Park to the east. Of the total 1,168,000 ha area, 648,000 ha are parks, recreation areas, private lands and tree farm licenses which were not part of the areas sampled for this study.

Purpose of the audit and application of the results

It is often asked, "How accurate is the current inventory?" To answer this important question, the Ministry of Forests has developed an inventory audit methodology specifically designed to test the overall accuracy of estimates of the total standing volume in each timber supply area.

This inventory audit methodology entails sampling three primary components of the inventory: mature forests, immature forests and non-forest areas.

The objective of the inventory audits program is to help identify TFLs or TSAs where the forest inventory needs attention. Enough samples are taken to ensure statistically reliable results for the TSA as a whole.

The audit conducted in the Fraser TSA was unique in that two independent studies were conducted in this management unit. Results from an initial audit conducted in 1994 raised some concerns about the timber volumes in the operable portion of the TSA. To confirm and validate the trends indicated by the initial study, a second study was conducted in the summer of 1995, focusing on the operable land base. This report describes the sampling process and analysis, and summarizes the results both from the initial (1994) study and from the 1994 and 1995 sampling combined.

The amount of data collected during audits is not sufficient to make statistically reliable conclusions about localized specific areas or tree species. For example, any overall differences highlighted by the audit could result from problems with one tree species, from part of the land base (such as high elevation rather than lower elevation areas), from one age group of forest stands, or from a combination of these and other factors. As a consequence, general audit results cannot appropriately be used to adjust information about the forests currently available for timber harvesting since this area constitutes only a portion of the total forested area in the TSA.

The audits provide information that may be useful to the chief forester during determinations of the allowable annual cut—offering a general assessment of the uncertainty associated with mature timber volumes, immature site index, and the non-forest classification. However, the audit results cannot justifiably be used to make specific adjustments to growth and yield and other information used in timber supply analysis and allowable annual cut determinations.

Methods

Current inventory

There are 36 TSAs in British Columbia, varying in size from approximately 200 000 hectares to 13 000 000 hectares. Inventories of each TSA are conducted through a multi-stage process. Polygons (a boundary drawn around a forest stand of similar characteristics) are first delineated from 1:15 000 scale aerial photographs. Photo-interpretation is then used to produce data on a number of attributes for each polygon. These attributes include species composition, stand height, age, and crown closure. Timber volume is then estimated indirectly using the photo-interpreted variables and an empirical yield model.

To keep estimates current, inventories are regularly updated to account for forest growth, and for depletions due to harvesting, fire losses, and the impact of insects and disease. Empirical yield models, such as the Ministry of Forests Variable Density Yield Prediction (VDYP) computer model, are used to update the inven-

tory for forest growth. Field visits, satellite imagery and aerial photographs may be used to update the inventory for depletion.

Inventory audit procedures

The inventory audit tests three components of the current inventory. The first component is the mature forested areas (forest stands greater than 60 years of age). The inventory audit tests the accuracy of the mature timber volume. The second component tested is immature stands (less than 60 years of age but greater than the silvicultural classification of free growing). The audit tests the accuracy of the site growth potential (site index) assignment for these stands. The third audit test is of the photo-classification accuracy of the non-forest classification component of the inventory (areas such as lakes, gravel pits and alpine meadows).

Mature component assessment criteria

Testing the mature component of the inventory compares the existing inventory's estimate of the mean mature volume per hectare for the TSA (called the *inventory volume*), and a new estimate of the mean mature volume per hectare for the TSA obtained from the audit samples (called the *audit volume*).

The difference between these two estimates is called the total bias. A test is conducted on this bias to determine if it is statistically significant. This test establishes whether there are detectable differences between the audit volume estimate and the inventory volume estimate, for the total forested area of the TSA.

If the total bias is found to be statistically significant, further analyses are conducted to determine if the specific source of bias within the inventory is one of the following:

- *classification bias:* This is caused by incorrectly estimating the polygon attributes; and
- *model bias:* This is caused by poor prediction from the yield model, which was developed for large areas of the province and was not designed for specific management units.

The analysis to determine the source of bias uses an estimate of the mean mature volume per hectare for the TSA called the *ground attribute volume*. This is calculated from audit sample attributes (stock and stand table estimates of species composition and stocking, and ground-based averages of top height and age), along with crown closure taken from the original map label, using the yield prediction model. The difference between the ground attribute volume estimate and the audit volume estimate approximates the bias associated with the yield model. The difference between the audit volume estimate and the inventory volume estimate not accounted for by the model bias approximates the bias associated with the inventory classification attributes. Once the source is identified, further analyses may be done on the attributes or the model itself.

Immature component assessment criteria

Accuracy of the inventory classification for immature stands is tested by examining the site index assignment. Since the immature forest stand site index provides an estimate of site productivity, its accuracy affects the projection of long-term harvest levels.

Data gathered is examined to determine how closely the audit and inventory site indices match for individual samples, and to explore potential trends.

Non-forest component assessment criteria

The audit test for the non-forest component of the inventory assesses the accuracy of the non-forest classification assignment. An air photo interpreter certified by the Ministry of Forests compares the non-forest inventory classification to a suitably-scaled forest cover aerial photograph. Classification accuracy is rated from a point scoring scheme to determine an overall accuracy percentage. The acceptance criteria for this test is 85% or higher.

Fraser TSA audit sampling procedures

The Fraser sample used updated maps based on inventories originally conducted in 1960 to 1962 and in 1970 to 1974. A list of all polygons identified on these maps was produced and sorted on a number of stand characteristics (site quality, age, and species group). Polygons were systematically selected from this list by a process designed to produce a representative sample of the TSA.

In the 1994 audit, for the mature forested component of the inventory audit, a random sample of 50 forested polygons from the total forested area in the TSA were selected for sampling. Only 46 polygons were actually sampled in the field because snowfall stopped the field work before all data could be obtained.

Up to four full-measure prism plots, and five count plots, were established within each of the 46 sample polygons. The plots were located systematically, using a square grid and a random start point. The grid interval distance varied with polygon size. To reduce sample costs for large or irregular polygons, only a randomly selected portion of the polygon was sampled. In

total, about 184 full-measure and 230 count plots were established. Field data collection and compilation followed Ministry of Forests cruising and cruise compilation procedures. The objective was to obtain audit volumes that were comparable (in terms of utilization standards and merchantability definitions) to the inventory volumes that are produced from the VDYP yield model.

The VDYP system produces net merchantable volume per hectare defined as stem volume inside bark of all live trees excluding a 10 cm diameter inside-bark top, a 30 cm high stump, and decay (as estimated from Ministry loss factors). This volume is calculated for a utilization standard defined as all live trees of 17.5+ cm dbh. Dead potential and veteran trees are not included in the VDYP system volume estimates. When considering the audit results, it should be noted that there are some differences between the utilization standards applied in the audit and those used operationally.

The audit volume estimates were then compared to the inventory volume estimates (from VDYP) to test the validity of the current inventory. Ratios of audit volume to inventory volume were calculated to test for significant differences. The precision of the inventory volume estimates—how well the inventory volume estimate corresponds to the audit volume estimate on a sample by sample basis—were assessed by measuring their statistical correlation. The data were then post-stratified to detect trends related to the operable and inoperable forested land base distribution of the sampled polygons.

For the immature forested component, a random sample of 20 polygons were selected for sampling. One polygon was not sampled because of heavy snowfall. Up to six inventory ground calls were established within each of the 19 polygons where field sampling was possible. The plots were located along a single transect line that was considered representative of the site productivity (site index) of the stand. In total, approximately 114 ground calls were established. Field data collection followed the standard Ministry of Forests inventory ground call procedures. The location of the sample transect was subjective. Since the magnitude of bias caused by this process is unknown, the reported results and their interpretations for the immature forested component of the inventory should be used with caution.

For the audit of the non-forest component of the inventory, a random sample of 30 non-forest polygons were selected. Standard Ministry of Forests inventory air photo classification techniques were used to compare the 30 non-forest polygon classification assignments to corresponding air photo checks.

Inventory audit results

Analysis of mature volumes

The results of the inventory audit for mature volume statistical analyses at the 17.5+ cm dbh utilization limit for the total forested area are given in Table 1.

	Audit Volume Estimate	Inventory Volume Estimate	Ground Attribute Volume Estimate
Number of Samples	46	46	43
Mean (m^3/ha)	425	510	443
Coefficient of variation (%)	49	43	40
Standard error (m^3/ha)	30.64	32.13	27.33
Sampling Error (%)	14.5	12.7	12.5
95% Confidence Interval (m^3/ha)	363-486	445-575	388-498

Correlation coefficient r = 0.531
Ratio of means (audit/inventory volume estimates) and sampling error at 95% confidence interval = 0.83 ±0.11

Table 1. Statistics for the audit volume and inventory volume estimates at 17.5 cm+ dbh utilization for Fraser TSA.

audit volume estimate	363	425	486		
inventory volume estimate			445	510	575
ground attribute volume estimate	388	443	498		

Table 2: Bar graph representation of 95% confidence intervals in m^3/ha

The calculated correlation coefficient of 0.531 for the audit and inventory volume estimates indicates a moderate relationship among individual samples.

There is an 85 m^3/ha difference between the means of the inventory estimate for mature volume (510 m^3/ha) and the audit estimate (425 m^3/ha). This difference is statistically significant, 19 times out of 20, for the mature component of the total forested area of the TSA.

Since there was a statistically significant difference between the two estimates, the ground attribute volume was calculated from the VDYP model. Top height was not available for three samples hence the ground attribute volume estimates are based on 43 samples. The estimated mean ground attribute volume was 443 m^3/ha.

The difference between the ground attribute volume and the audit volume estimates was 18 m^3/ha. The difference between the inventory volume and the ground attribute volume was 67 m^3/ha. This suggests that most of the total bias in the inventory is associated with the

classification attributes.

Analysis of operable and inoperable volumes

To provide audit results more likely to be applicable to the timber supply planning process, an approximation was made of the forested areas considered currently available for timber harvesting (called *operable* areas). The audit results were post-stratified based on this approximation. The results of the statistical analysis of the audit for the operable forested area are presented in Table 3.

	Operable Audit Volume Estimate	Operable Inventory Volume Estimate	Operable Ground Attribute Volume Estimate
Number of Samples	27	27	27
Mean (m^3/ha)	403	547	439
Coefficient of variation (%)	49	45	40
Standard error (m^3/ha)	37.78	47.39	33.64
Sampling Error (%)	19.3	17.8	15.8
95% Confidence Interval (m^3/ha)	326-481	450-645	370-508

Correlation coefficient r = 0.633
Operable ratio of means (audit/inventory volume estimates) and sampling error at 95% confidence interval = 0.74 ±0.12

Table 3. Statistics for the operable audit volume, inventory volume and ground attribute volume estimates at 17.5 cm+ dbh utilization for Fraser TSA.

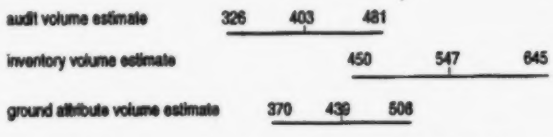

Table 4: Bar graph representation of 95% confidence intervals in m^3/ha for the operable forested area.

For the 27 samples located within the operable forested area, the mean audit volume was 403 m^3/ha and the corresponding inventory volume was 547 m^3/ha. The difference of 144 m^3/ha between the two estimates was statistically significant, 19 times out of 20.

The ground attribute volume for the operable samples was calculated from the VDYP model to determine the source of the bias. The estimate of the mean ground attribute volume was 439 m^3/ha, which suggests that the majority of the total bias in the inventory for operable forested areas is associated with the classification attributes. It was not possible, based on this sample, to specifically identify the source of the classification bias.

Out of the original 46 samples, there were 19 samples which were within the inoperable (i.e. not currently available for timber harvesting) forested area. The results of the statistical analysis of the audit for the inoperable forested area are presented in Table 5.

	Inoperable Audit Volume Estimate	Inoperable Inventory Volume Estimate
Number of Samples	19	19
Mean (m^3/ha)	455	457
Coefficient of variation (%)	49	35
Standard error (m^3/ha)	51.62	37.02
Sampling Error (%)	23.8	17.0
95% Confidence Interval (m^3/ha)	347-564	379-534

Correlation coefficient r = 0.518
Ratio of means (audit/inventory volume estimates) and sampling error at 95% confidence interval = 1.00 ±0.21

Table 5. Statistics for the inoperable audit volume and inventory volume estimates at 17.5 cm+ dbh utilization for Fraser TSA.

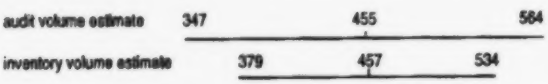

Table 6: Bar graph representation of 95% confidence intervals in m^3/ha for the inoperable forested area.

For the 19 samples located within the inoperable forested areas, the mean audit volume was 455 m^3/ha and the corresponding inventory volume was 457 m^3/ha. The difference between these two estimates was not statistically significant.

Analysis of operable volumes including 1995 augmented samples

Due to the relatively large sampling error and the significant questions raised for the operable component of the 1994 audit, it was decided to sample an additional 100 polygons in the operable forested area in the Fraser TSA. The files used by Timber Supply Branch during the Fraser Timber Supply Review were used to define the operable portion of the management unit. Polygons in the operable portion were sorted by the same criteria as the original study, and a systematic sample of 100 additional polygons were selected for sampling during the 1995 field season. The results from these additional 100 samples were combined with the 27 operable samples from the initial audit to form an augmented audit for the operable forested area comprised of 127 samples. The results of the statistical

analysis of the augmented audit for the operable forested area are presented in Table 7.

	Operable Audit Volume Estimate	Operable Inventory Volume Estimate	Operable Ground Attribute Volume Estimate
Number of Samples	127	127	127
Mean (m^3/ha)	452	584	525
Coefficient of variation (%)	44	40	39
Standard error (m^3/ha)	17.49	20.57	18.07
Sampling Error (%)	7.7	7.0	6.8
95% Confidence Interval (m^3/ha)	417-487	544-625	489-561

Correlation coefficient r = 0.517
Ratio of means (audit/inventory volume estimates) and sampling error at 95% confidence interval = 0.77 ±0.06

Table 7. Statistics for the operable audit volume, inventory volume and ground attribute volume estimates at 17.5 cm+ dbh utilization for Fraser TSA based on the augmented audit results.

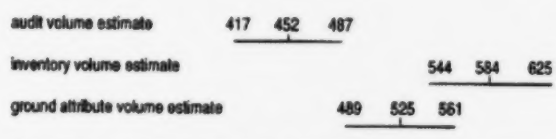

Table 8: Bar graph representation of 95% confidence intervals in m^3/ha for the operable forested area based on the augmented audit results.

For the 127 samples located in the operable forested area, the mean audit volume was 452 m^3/ha and the corresponding inventory volume was 584 m^3/ha. The difference of 132 m^3/ha between the two estimates was statistically significant, 19 times out of 20.

The estimated ground attribute volume was 525 m^3/ha. The difference between the ground attribute volume and the audit volume estimates was 73 m^3/ha. The difference between the inventory volume and the ground attribute volume estimates was 59 m^3/ha. This suggests that both classification attribute bias and model bias contribute to the total bias observed in the inventory for operable forested areas.

Post-stratification of the augmented audit results for operable forested areas indicated that the trend for the inventory to overestimate volume was consistent across all major species and age groupings.

Analysis of immature inventory classification

Out of 19 stands sampled in the field the inventory correctly identified site index within ± 5 m of the audit site index for ten stands. The inventory site index was more than 5 m lower than the audit site index for four stands, and more than 5 m higher for five stands.

Analysis of non-forest inventory classification

Thirty stands classified as non-forest were assessed for their inventory assignment accuracy. The resulting score was 78%. This was less than the provincial minimum standard of 85%.

Discussion and conclusions

The objective of the inventory audit in the Fraser TSA was to assess the overall accuracy of the current (1960-62 and 1970-74) Ministry of Forests inventory. The mature, immature and non-forest components were tested.

The results of the initial audit for the mature forested component of the inventory suggest that the inventory may overestimate volume. When the data is post-stratified it becomes apparent that the bias is largely in the operable forested area of the Fraser TSA.

To confirm these findings, and additional 100 samples were taken in the operable forested area. The combined samples were analyzed and indicate that the inventory overestimates volume in the operable forested area.

The results from this inventory audit have been forwarded to the Ministry of Forests Timber Supply Branch for their consideration in the upcoming timber supply analysis for the Fraser TSA. It should be noted that the Fraser TSA is currently undergoing a reinventory, the standards for which will be consistent with the new Vegetation Resources Inventory.

Audit results for the immature component of the inventory suggests an acceptable level of accuracy for site index assignment in young stands.

Although not within provincial standards, the differences found in the assessment of the non-forest classification in this TSA are considered to be minor. The majority of the differences are due to minor changes in classification standards that were not reflected on the existing maps. All major classification criteria were correct.

This study has undergone an external review by Dr. Don Munro, formerly of the UBC Faculty of Forestry, now in private consultancy. Dr. Munro concluded that the statistical audit execution and compilation were consistent with generally accepted timber inventory and statistical estimation principles, and that the audit fairly presents the final average volumes.

Glossary

accuracy: A measure of the closeness of an estimate to the true value.

allowable annual cut: The rate of timber harvesting specified for an area of land.

analysis unit: The basic building block around which inventory data and other information are assembled for use in forest planning models. Analysis units represent the general level of aggregation, or detail, at which a timber supply analysis is carried out. They are normally defined by tree species and site qualities.

bias: The quality of a measurement device or procedures that tends to result in a systematic misrepresentation of what is being measured.

coefficient of variation: A relative measure of the variation of the population calculated as the ratio between the standard deviation and the mean value.

confidence interval: The range of values within which the population parameter is expected to lie.

confidence level: The estimated probability that a population parameter lies within a given confidence interval.

correlation coefficient: A measure of the relationship between two variables. A value of 0 for the correlation coefficient indicates a random relationship whereas a value of ±1 indicates a perfect positive or negative linear correspondence.

diameter at breast height (dbh): The stem diameter (outside-bark) of a tree measured at breast height (1.3 metres above the point of germination) to the nearest millimetre.

field visitations: Ground level field procedures designed to provide physical verification of polygon inventory attributes.

free growing (crop): A crop of healthy trees of a commercially valuable species, the growth of which is not impeded by competition from plants, shrubs or other trees.

inoperable: Refers to areas having merchantable timber that cannot be harvested economically using current harvesting technology because of some physical barrier (such as a hanging valley), and to areas containing small patches of overmature timber surrounded by large areas of young stands.

mean: The average value of a set of observations.

pre-inventory assessments: Pre-inventory analyses are inventory activities to evaluate the existing forest inventory as the basis for deciding whether to reinventory or update the current inventory, and to document the existing inventory, maps, and photos to support the execution of the reinventory or update if required.

ratio estimate: The ratio between two different estimates.

representative: The quality of a sample having the same characteristics as the population from which it is selected.

sampling: The process of selecting observations.

sampling error: The error attributed to sampling procedures. It is calculated as standard error multiplied by a t-value corresponding to a stated confidence level. The sampling error is often expressed as a percentage of the mean.

significant difference: An expression used in reference to the results of a statistical test in which either two or more estimates are compared or an estimate is compared to a fixed value. If the observed difference is greater than what might be expected as a chance occurrence due to the sampling procedures, the difference is said to be statistically significant.

site index: A measure of site productivity. Site indices are based on tree height as a function of stand age and are usually expressed graphically as site index curves. A number of site index curves have been developed for British Columbia's major commercial tree species.

standard error: An expression of the absolute variability of an estimate. It is calculated as the standard deviation divided by the square root of the number of samples.

standard deviation: A measure of the variation of the population.

timber supply analysis: The technical process of amalgamating land management information into computer systems that predict the amount of timber available for harvest over given time periods.

timber supply area: An integrated resource management unit established in accordance with section 6 of the *Forest Act*.

tree farm license: An integrated resource management unit established in accordance with section 28 of the *Forest Act*.

For more information

For more information or to obtain other inventory audit reports, contact: Director, Resources Inventory Branch, 722 Johnson Street, Victoria, B.C., Canada V8W 3E7, phone 604-387-1314, fax 387-5999, via e-mail at RIBinfo@galaxy.gov.bc.ca, or visit our web site at http://www.for.gov.bc.ca/resinv/homepage.htm on the Internet.

June 1996

Fraser TSA Inventory Audit

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The objective of inventory audits is to help estimate the statistical precision and bias of the forest inventories in TFLs and TSAs. Enough samples are taken to ensure statistically reliable results for the TFL or TSA as a whole.

The audit conducted in the Fraser TSA was unique in that two independent studies were conducted in this management unit. Results from an initial audit conducted in 1994 raised some concerns about the timber volumes in the operable portion of the TSA. To confirm and validate the trends indicated by the initial study, a second study was conducted in the summer of 1995, focusing on the operable land base. This report describes the sampling process and analysis, and summarizes the results both from the initial (1994) study and from the 1994 and 1995 sampling combined.

The amount of data collected, however, is not sufficient to make statistically reliable conclusions about specific areas or tree species. For example, any overall differences highlighted by the audit could result from problems with one tree species, from part of the land base (such as high elevation rather than lower areas), from one age group of forest stands, or from a combination of these and other factors. As a consequence, general audit results cannot appropriately be used to adjust information about the forests currently available for timber harvesting since this area constitutes only a portion of the total forested area in the TSA.

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To keep estimates current, inventories are regularly updated to account for forest growth, and for depletions due to harvesting, fire losses, and the impact of insects and disease. Empirical yield models, such as the Ministry of Forests Variable Density Yield Prediction (VDYP) computer model, are used to update the inventory for forest growth. Field visits, satellite imagery and aerial photographs may be used to update the inventory for depletion.

Inventory audit procedures

The inventory audit tests three components of the current inventory. The first component is the mature forested areas (forest stands greater than 60 years of age). The inventory audit tests the accuracy of the mature timber volume and also examines the species classification accuracy for the mature forested areas. The second component tested is immature stands (less than 60 years of age but greater than the silvicultural classification of free growing). The audit tests the accuracy of the site growth potential (site index) assignment and the species classification accuracy for these stands. The third audit test is of the photo-classification accuracy of the non-forested classification component of the inventory (areas such as lakes, gravel pits and alpine meadows).

Mature component assessment criteria

Testing the mature component of the inventory compares the existing inventory's estimate of the mean mature volume per hectare for the TSA (called the *inventory volume*), and a new estimate of the mean mature volume per hectare for the TSA obtained from the audit samples (called the *audit volume*).

The difference between these two estimates is called the total bias. Two tests are conducted on this bias to determine if it is statistically significant. These tests establish whether there are detectable differences between the audit volume estimate and the inventory volume estimate, for the total forested area of the TSA. In the first test, the ratio of the means of the two volume estimates and the confidence interval for this ratio are calculated. If the value 1.0 is within this 95% confidence interval, the inventory volume is considered acceptable. In the second test, a paired sample t-test (Walpole 1974) is used to determine whether the mean difference between the two estimates is statistically significant.

If these two tests find the total bias to be statistically significant, further analyses are conducted to determine if the specific source of bias within the inventory is one of the following:

- *classification bias:* This is caused by incorrectly estimating the polygon attributes; and/or
- *model bias:* This is caused by poor prediction from the yield model, which was developed for large areas of the province and was not designed for specific management units.

The analysis to determine the source of bias uses an estimate of the mean mature volume per hectare for the TSA called the *ground attribute volume*. This is calculated from audit sample attributes (stock and stand table estimates of species composition and stocking, and ground-based averages of top height and age), along with crown closure taken from the original map label, using the yield prediction model. The difference between the ground attribute volume estimate and the audit volume estimate approximates the bias associated with the yield model. The difference between the audit volume estimate and the inventory volume estimate not accounted for by the model bias approximates the bias associated with the inventory classification attributes. Once the source is identified, further analyses may be done on the attributes or the model itself.

Note that the analyses using ground attribute volume can only approximate the model and classification bias. Model and classification bias are usually confounded to some degree and are difficult to separate. For example, there is model error inherently associated with the inventory attributes since inventory heights are updated or projected. There may also be errors related to stand dynamics that are influenced by the length of time between the original inventory and the audit (the projection period). In addition, model error may exist as a result of a bias associated with the plots used to fit the VDYP model. Analyses using ground attribute volume cannot be used to precisely identify the source of bias in an inventory, however, they may be useful to indicate potential areas for further investigation.

The species classification accuracy for the mature component is also examined. Species composition is generally determined by visually estimating percent crown cover by species from aerial photographs. For analysis and general reporting purposes these species types are then combined into 17 broad aggregations of species groupings called growth type groups. Growth type groups are the primary basis for species type stratification used in the timber supply analysis process. The accuracy of the species composition attribute can be judged by comparing how often the inventory growth type group classification agrees with the audit sample classification. A statistical measure called the K statistic is used to evaluate this level of agreement (Cohen 1960). The K statistic compares the observed level of agreement (the proportion of growth type group matches) with the expected level of agreement. A "high level of agreement" for the K statistic is based on a 5% significance level. It is assumed that the audit samples represent the entire polygon and that a ground based species composition derived from a volume summary is compatible with a photo based species estimate.

Immature component assessment criteria

Accuracy of the inventory classification for immature stands is tested by examining the site index assignment. Since the immature forest stand site index provides an estimate of site productivity, its accuracy affects the projection of long-term harvest levels.

Data gathered is examined to determine how closely the audit and inventory site indices match for individual samples, and to explore potential trends.

The species classification accuracy for the immature component of the inventory is also examined. Using the same approach that was outlined in the mature component section, a K statistic is used to determine the level of agreement in the growth type group classification between the audit and the inventory.

Non-forest component assessment criteria

The audit test for the non-forest component of the inventory assesses the accuracy of the non-forest classification assignment. An air photo interpreter certified by the Ministry of Forests compares the non-forest inventory classification to a suitably-scaled forest cover aerial photograph. Classification accuracy is rated from a point scoring scheme to determine an overall accuracy percentage. The acceptance criteria for this test is 85% or higher.

Fraser TSA audit sampling procedures

The Fraser TSA sample uses updated maps based on an inventory originally conducted in 1960 to 1962 and in 1970 to 1974. A list of all forested polygons identified on these maps was produced and sorted on a number of stand characteristics (site quality, age, and species group). Polygons were systematically selected from this list by a process designed to produce a representative sample of the TSA.

In the 1994 audit, for the mature forested component of the inventory audit, a random sample of 50 forested polygons from the total forested area in the TSA were selected for sampling. Only 46 polygons were actually sampled in the field because snowfall stopped the field work before all data could be obtained.

Up to four full-measure prism plots, and five count plots, were established within each of the 46 sample polygons. The plots were located systematically, using a square grid and a random start point. The grid interval distance varied with polygon size. To reduce sample costs for large or irregular polygons, only a randomly selected portion of the polygon was sampled. In total, about 184 full-measure and 230 count plots were established. Field data collection and compilation followed Ministry of Forests cruising and cruise compilation procedures. The Kozak volume function was used in the volume compilation process. The objective was to obtain audit volumes that were comparable (in terms of utilization standards and merchantability definitions) to the inventory volumes that are produced from the VDYP yield model.

The VDYP system produces net merchantable volume per hectare defined as stem volume inside bark of all live trees excluding a 10 cm diameter inside-bark top, a 30 cm high stump, and decay (as estimated from Ministry loss factors). This volume is calculated for a utilization standard defined as all live trees of 17.5+ cm dbh. Dead potential and veteran trees are not included in the VDYP system volume estimates. When considering the audit results, it should be noted that there are some differences between the utilization standards applied in the audit and those used operationally.

The audit volume estimates were then compared to the inventory volume estimates (from VDYP) to test the validity of the current inventory. The ratio of mean audit volume to mean inventory volume, and the confidence interval for this ratio, were calculated to test for significant differences. In addition, a paired sample t-test was also performed. The precision of the inventory volume estimates – how well the inventory volume estimate corresponds to the audit volume estimate on a sample by sample

basis—were assessed by measuring their statistical correlation. A K statistic was calculated to determine if the observed level of growth type group agreement between the inventory and the audit was statistically significant. The data was then post-stratified to detect trends related to the operable and inoperable forested land base distribution of the sampled polygons.

From the immature forested component, a random sample of 20 polygons were selected for sampling. One polygon was not sampled because of heavy snowfall. Up to six inventory ground calls were established within each of the 19 polygons where field sampling was possible. The plots were located along a single transect line that was considered representative of the site productivity (site index) of the stand. In total, approximately 114 ground calls were established. Field data collection followed the standard Ministry of Forests inventory ground call procedures. The location of the sample transect was subjective. Since the magnitude of bias caused by this process is unknown, the reported results and their interpretations for the forested component of the inventory should be used with caution.

Site index was calculated using the site index curves in the most recent version of Freddie (the Ministry of Forests' Site Index Estimation Program), using total age (or breast height age where available) and top height. This audit site index was compared with the inventory site index indicated on the Ministry of Forests' forest cover attributes file (i.e. Forest Inventory Planning (FIP) file). As for the mature component, a K statistic was used to evaluate the growth type group classification.

For the audit of the non-forest component of the inventory, a random sample of 30 non-forest polygons were selected. Standard Ministry of Forests inventory air photo classification techniques were used to compare the 30 non-forest polygon classification assignments to corresponding air photo checks.

Inventory audit results

Analysis of mature volumes

The results of the inventory audit for mature volume statistical analyses at the 17.5+ cm dbh utilization limit for the total forested area are given in Table 1.

	Audit Volume Estimate	Inventory Volume Estimate	Ground Attribute Volume Estimate
Number of Samples	46	46	43
Mean (m^3/ha)	425	510	443
Coefficient of variation (%)	49	43	40
Standard error (m^3/ha)	30.64	32.13	27.33
Sampling Error (%) at 95% confidence level	14.5	12.7	12.5
95% Confidence Interval (m^3/ha)	363–486	445–575	388–498

Table 1: Statistics for the audit volume, inventory volume and ground attribute volume estimates at 17.5 cm+ dbh utilization for Fraser TSA.

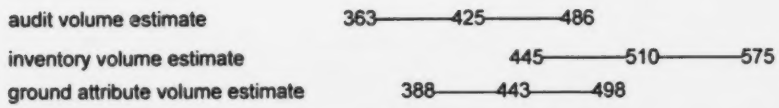

Table 2: Bar graph representation of 95% confidence intervals in m^3/ha

The calculated correlation coefficient for the audit and inventory volume estimates is 0.531, indicating a moderate relationship among individual samples. There is an 85 m^3/ha difference between the inventory estimate for mature volume (510 m^3/ha) and the audit estimate (425 m^3/ha). This difference is statistically significant 19 times out of 20 for the mature component of the total forested area of the Fraser TSA.

Since there was a statistically significant difference between the two estimates, the ground attribute volume was calculated from the VDYP model. Top height was not available for three samples hence the ground attribute volume estimates are based on 43 samples. The estimated mean ground attribute volume was 443 m^3/ha.

The difference between the ground attribute volume and the audit volume estimates was 18 m^3/ha. The difference between the inventory volume and the ground attribute volume was 67 m^3/ha. This suggests that most of the total bias in the inventory is associated with the inventory classification attributes.

Figures 1 to 3 provide a graphical representation of the total bias, the model bias and the classification bias for the mature component of the total forested area of the Fraser TSA. The letter codes on the scatter plots correspond to the growth type groups for the polygons as assigned in the inventory (see Table 3). The correlation coefficient, the ratio and its confidence interval, and the results of the paired sample t-test accompany each graph.

Growth Type Group Letter code	Growth Type Group Species Composition	# of polygons
A	F, FPI, F Decid., Pw	5
B	FC and FCy, FH, FS	8
E	C, CF, CH	3
G	HF, HC, HB, HS	10
H	B, BH, BS	15
J	SF, SH (and SC), SB	1
M	PIF, PIS (and PIB)	2
P	D Decid., Mb, Bi, A Decid.	2

Table 3: Distribution of growth type groups (as assigned by the inventory) for the mature sample polygons.

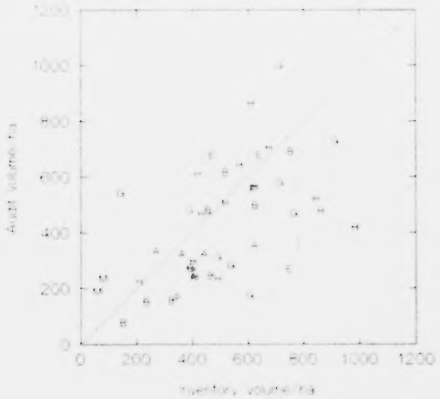

Figure 1: ***Total Bias*** Audit volume versus inventory volume, by inventory growth type group. Diagonal line represents a perfect correlation.

Correlation coefficient: **r = 0.531**
(p-value < 0.001)

Ratio of means = 0.83
95% confidence interval for ratio of means:
0.72 — 0.94

Mean difference (audit volume - inventory volume)
= -85.18 m^3/ha (p-value* = 0.008)

** a p-value < 0.05 indicates statistical significance (at a 5% significance level)*

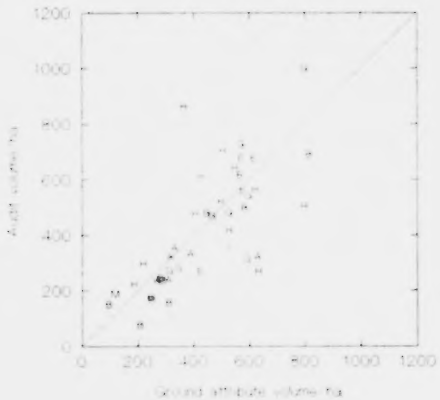

Figure 2: ***Model Bias*** Audit volume versus ground attribute volume, by inventory growth type group. Diagonal line represents a perfect correlation.

Correlation coefficient: **r = 0.708**
(p-value < 0.001)

Ratio of means = 0.96
95% confidence interval for ratio of means:
0.85 — 1.06

Mean difference** (audit volume - ground attribute volume) = -18.56 m^3/ha (p-value = 0.429)

***based on 43 paired samples*

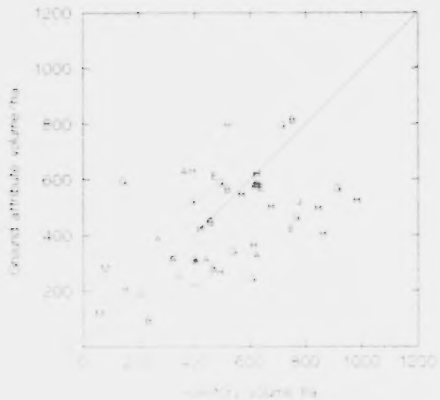

Figure 3: ***Classification Bias*** Ground attribute volume versus inventory volume, by inventory growth type group. Diagonal line represents a perfect correlation.

Correlation coefficient: **r = 0.487**
(p-value = 0.001)

Ratio of means = 0.87
95% confidence interval for ratio of means:
0.76 — 0.98

Mean difference** (ground attribute volume - inventory volume) = -66.46 m^3/ha
(p-value = 0.041)

***based on 43 paired samples*

Analysis of operable and inoperable volumes

To provide audit results more likely to be applicable to the timber supply planning process, an approximation was made of the forested areas considered currently available for timber harvesting (called *operable* areas). The audit results were post-stratified based

on this approximation. The results of the inventory audit for the operable and inoperable forested areas in the TSA are given in Table 4.

	Operable			Inoperable		
	Audit Volume Estimate	Inventory Volume Estimate	Ground Attribute Volume Estimate	Audit Volume Estimate	Inventory Volume Estimate	Ground Attribute Volume Estimate
Number of Samples	27	27	27	19	19	16
Mean (m^3/ha)	403	547	439	455	457	450
Coefficient of variation (%)	49	45	40	49	35	43
Standard Error (m^3/ha)	37.78	47.39	33.64	51.62	37.02	48.04
Sampling Error (%) at 95% confidence level	19.3	17.8	15.8	23.8	17.0	22.8
95% Confidence Interval	326–481	450–645	370–508	347–564	379–534	347–552

Table 4: Statistics for the audit, inventory and ground attribute volume estimates at 17.5+ cm dbh utilization for operable and inoperable forested areas in the Fraser TSA.

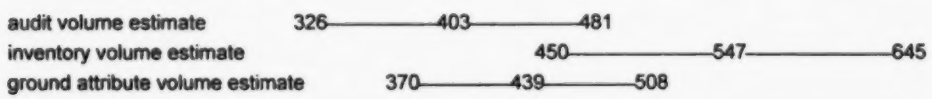

Table 5: Bar graph representation of 95% confidence intervals in m^3/ha for the operable forested area.

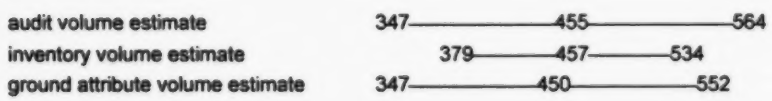

Table 6: Bar graph representation of 95% confidence intervals in m^3/ha for the inoperable forested area.

For the 27 samples located within the operable forested area, the mean audit volume was 403 m^3/ha and the corresponding inventory volume was 547 m^3/ha. The difference between these two estimates was statistically significant, 19 times out of 20. However, due to the limited sample size and relatively high variability associated with these volume estimates, the conclusions regarding the inventory within the operable forested area (based on this sample of 27) must be viewed with caution.

For the 19 samples located within the inoperable forested area, the mean audit volume was 455 m^3/ha and the corresponding inventory volume was 457 m^3/ha. This difference was not statistically significant.

Figures 4 to 6 provide a graphical representation of the total bias, the model bias and the classification bias for the operable forested area.

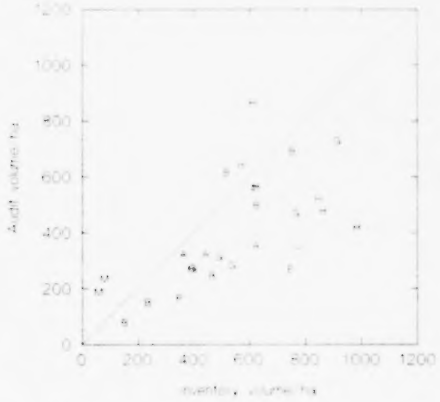

Figure 4: ***Total Bias for the Operable Forested Area*** Audit volume versus inventory volume, by inventory growth type group. Diagonal line represents a perfect correlation.

Correlation coefficient: **r = 0.633**
(p-value < 0.001)

Ratio of means = 0.74
95% confidence interval for ratio of means:
0.62 — 0.85

Mean difference (audit volume - inventory volume) = -144.14m^3/ha (p-value = 0.001)

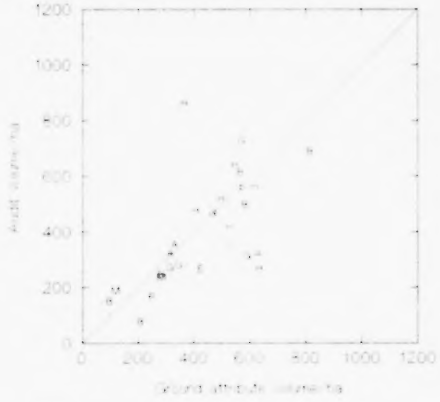

Figure 5: ***Model Bias for the Operable Forested Area*** Audit volume versus ground attribute volume, by inventory growth type group. Diagonal line represents a perfect correlation.

Correlation coefficient: **r = 0.621**
(p-value = 0.001)

Ratio of means = 0.92
95% confidence interval for ratio of means:
0.78 — 1.06

Mean difference (audit volume - ground attribute volume) = -35.59 m^3/ha (p-value = 0.266)

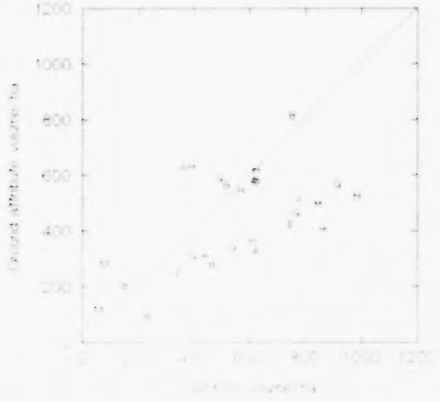

Figure 6: ***Classification Bias for the Operable Forested Area*** Ground attribute volume versus inventory volume, by inventory growth type group. Diagonal line represents a perfect correlation.

Correlation coefficient: **r = 0.582**
(p-value = 0.001)

Ratio of means = 0.80
95% confidence interval for ratio of means:
0.68 — 0.93

Mean difference (ground attribute volume - inventory volume) = -108.54m^3/ha (p-value = 0.010)

Figures 7 to 9 provide a graphical representation of the total bias, the model bias and the classification bias for the inoperable forested area.

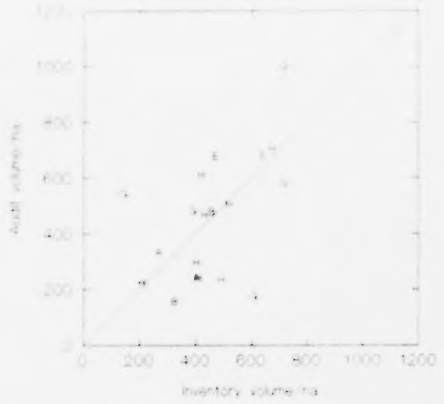

Figure 7: ***Total Bias for the Inoperable Forested Area*** Audit volume versus inventory volume, by inventory growth type group. Diagonal line represents a perfect correlation.

Correlation coefficient: **r = 0.518**
(p-value = 0.023)

Ratio of means = 1.00
95% confidence interval for ratio of means:
0.79 — 1.21

Mean difference (audit volume - inventory volume) = -1.40m^3/ha (p-value = 0.976)

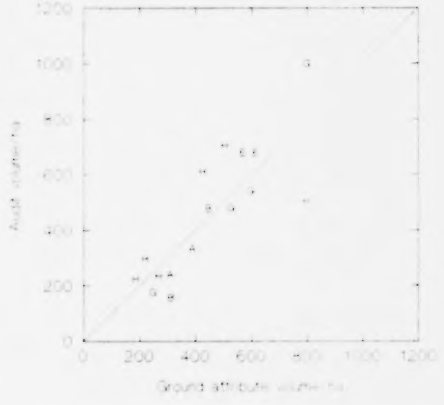

Figure 8: ***Model Bias for the Inoperable Forested Area*** Audit volume versus ground attribute volume, by inventory growth type group. Diagonal line represents a perfect correlation.

Correlation coefficient: **r = 0.829**
(p-value < 0.001)

Ratio of means = 0.93
95% confidence interval for ratio of means:
0.74 — 1.12

Mean difference (audit volume - ground attribute volume) = 10.17m^3/ha (p-value = 0.764)

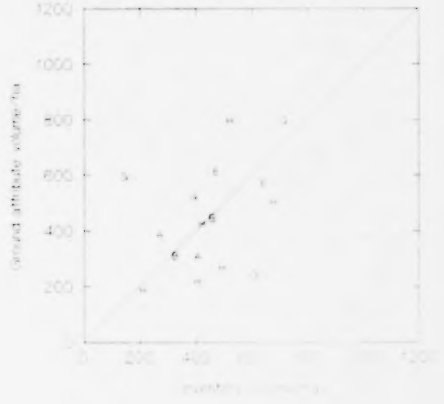

Figure 9: ***Classification Bias for the Inoperable Forested Area*** Ground attribute volume versus inventory volume, by inventory growth type group. Diagonal line represents a perfect correlation.

Correlation coefficient: **r = 0.375**
(p-value = 0.152)

Ratio of means = 1.01
95% confidence interval for ratio of means:
0.77 — 1.25

Mean difference (ground attribute volume - inventory volume) = 4.55 m^3/ha (p-value = 0.929)

Analysis of operable volumes including additional 1995 samples

Due to the relatively large sampling error and the significant questions raised for the operable component of the 1994 audit, it was decided to sample an additional 100 polygons in the operable forested area in the Fraser TSA. The files used by Timber Supply Branch during the Fraser Timber Supply Review were used to define the

operable portion of the management unit. Polygons in the operable portion were sorted by the same criteria as the original study, and a systematic sample of 100 additional polygons were selected for sampling during the 1995 field season. The results from these additional 100 samples were combined with the 27 operable samples from the initial audit to form an augmented audit for the operable forested area comprised of 127 samples. The results of the statistical analysis of the augmented audit for the operable forested area are presented in Table 7 (see Appendix A for the augmented sample data for the operable forested area).

	Operable		
	Audit Volume Estimate	Inventory Volume Estimate	Ground Attribute Volume Estimate
Number of Samples	127	127	127
Mean (m^3/ha)	452	584	525
Coefficient of variation (%)	44	40	39
Standard error (m^3/ha)	17.49	20.57	18.07
Sampling Error (%) at 95% confidence level	7.7	7.0	6.8
95% Confidence Interval (m^3/ha)	417–487	544–625	489–561

Table 7: Statistics for the audit volume, inventory volume and ground attribute volume estimates at 17.5 cm+ dbh utilization for Fraser TSA, based on 127 samples.

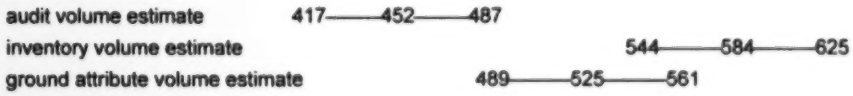

Table 8: Bar graph representation of 95% confidence intervals in m^3/ha for the operable forested area, based on 127 samples.

For the augmented sample of 127 in the operable forested area, the mean audit volume estimate was 452 m^3/ha and the corresponding mean inventory volume estimate was 584 m^3/ha. The difference of 132 m^3/ha is statistically significant, 19 times out of 20.

The estimated mean ground attribute volume was 525 m3/ha. The difference between the mean ground attribute volume and the mean audit volume was 73 m^3/ha. The difference between the mean inventory volume and ground attribute volume was 59 m^3/ha. This suggests that there is significant bias associated with both the model and the inventory classification attributes in the operable forested area.

The augmented sample of 127 in the operable forested area was post-stratified by a number of criteria, in an effort to more specifically determine the source of bias. Post-stratification by biogeoclimatic zone and subzone, supply block, inventory type groupings, and leading species did not reveal any consistent trends. Further analysis of the audit data for the Fraser TSA is currently underway.

Figures 10 to 12 provide a graphical representation of the total bias, the model bias and the classification bias for the operable forested area in the Fraser TSA, based on the augmented sample of 127 polygons.

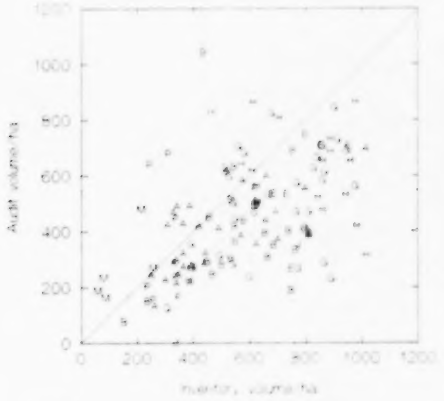

Figure 10: ***Total Bias for the Operable Forested Area based on 127 samples*** Audit volume versus inventory volume, by inventory growth type group. Diagonal line represents a perfect correlation.

Correlation coefficient: **r = 0.517**
(p-value < 0.001)

Ratio of means = 0.77
95% confidence interval for ratio of means:
0.72 — 0.83

Mean difference (audit volume - inventory volume)
= -132.58m^3/ha (p-value < 0.001)

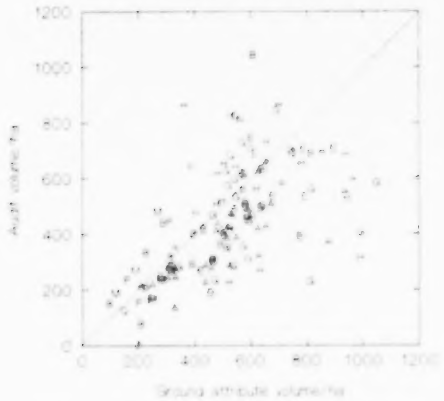

Figure 11: ***Model Bias for the Operable Forested Area based on 127 samples*** Audit volume versus ground attribute volume, by inventory growth type group. Diagonal line represents a perfect correlation.

Correlation coefficient: **r = 0.570**
(p-value < 0.001)

Ratio of means = 0.86
95% confidence interval for ratio of means:
0.80 — 0.92

Mean difference (audit volume - ground attribute volume) = -73.17m^3/ha (p-value < 0.001)

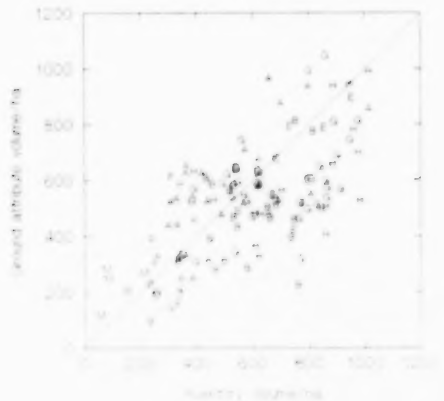

Figure 12: ***Classification Bias for the Operable Forested Area based on 127 samples*** Ground attribute volume versus inventory volume, by inventory growth type group. Diagonal line represents a perfect correlation.

Correlation coefficient: **r = 0.654**
(p-value < 0.001)

Ratio of means = 0.90
95% confidence interval for ratio of means:
0.85 — 0.95

Mean difference (ground attribute volume - inventory volume) = -59.41m^3/ha (p-value < 0.001)

Analysis of mature species classification

The analysis of the mature species classification was carried out for the 46 polygons sampled in the 1994 audit. The distribution of the growth type groups for the mature samples, as estimated by the inventory and by the audit, is provided in Table 9 (see Appendix B for a description of the species composition for each growth type group).

Overall, 74% of the growth type groups assigned in the inventory matched the growth type group assigned in the audit.

Audit Growth Type Group	Inventory Growth Type Group								Total
	A	B	E	G	H	J	M	P	
A	***3***	1	0	0	0	0	1	0	5
B	2	***7***	0	0	0	0	0	0	9
E	0	0	***2***	1	0	0	0	0	3
G	0	0	1	***8***	4	0	0	0	13
H	0	0	0	1	***11***	1	0	0	13
J	0	0	0	0	0	***0***	0	0	0
M	0	0	0	0	0	0	***1***	0	1
P	0	0	0	0	0	0	0	***2***	2
Total	5	8	3	10	15	1	2	2	46

Table 9: Mature sample growth type group distribution for the audit and the inventory. The bold italic entries on the diagonal in the table indicate a growth type group match between the audit and the inventory.

A K statistic was used to compare the observed level of agreement (the proportion of growth type group matches) with the expected level of agreement. The calculated Z-value for the K statistic was 8.924. Since this value is greater than the critical Z-value of 1.645 (at a 5% significance level), the K statistic indicated a high level of agreement between the inventory growth type group classification and the audit classification. However, these results should be interpreted with care. The assessment of the mature inventory classification is based on broad species groupings (i.e. growth type groups). In addition, the sample sizes in the inventory audit are smaller than are usually recommended for application of the K statistic.

Analysis of immature inventory classification

Out of 19 stands sampled in the field, the inventory correctly identified site index within ± 5 m of the audit site index for ten stands. The inventory site index was more than 5 m lower than the audit site index for four stands, and more than 5 m higher for five stands. These results are illustrated in Figure 13 (see Appendix C for the immature sample data).

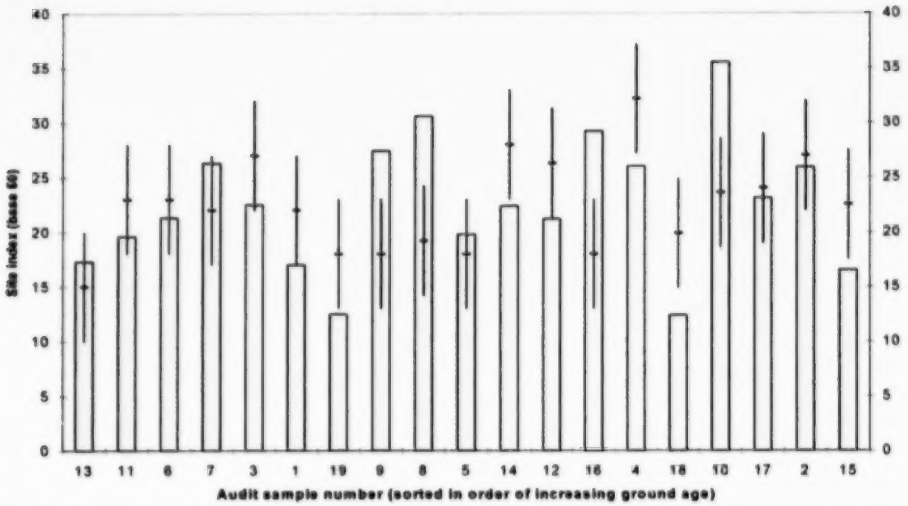

Figure 13: Comparison of audit and inventory site index values for immature stands. The shaded bars represent the audit site index. The tick marks on the vertical lines represent the inventory site index (the vertical lines have arbitrarily been set at ± 5 m around the inventory site index). The samples are sorted in order of increasing stand age, as estimated by the audit.

The distribution of the growth type groups for the 19 immature polygons, as estimated by the inventory and by the audit, is provided in Table 10. Overall, 47% of the growth type groups assigned in the inventory matched the growth type group assigned in the audit.

Audit Growth Type Group	Inventory Growth Type Group										
	A	B	C	E	F	G	H	J	L	P	Total
A	***0***	1	1	0	0	1	0	0	0	0	3
B	0	***2***	0	0	0	0	0	0	0	0	2
C	0	1	***0***	0	0	0	0	0	0	0	1
E	1	0	0	***0***	0	0	0	0	0	1	2
F	0	1	0	0	***0***	0	0	0	0	0	1
G	0	1	0	0	0	***2***	0	0	0	0	3
H	0	0	0	0	0	1	***3***	1	0	0	5
J	0	0	0	0	0	0	0	***0***	0	0	0
L	0	0	0	0	0	0	0	0	***1***	0	1
P	0	0	0	0	0	0	0	0	0	***1***	1
Total	1	6	1	0	0	4	3	1	1	2	19

Table 10: Immature sample growth type group distribution for the audit and the inventory. The bold italic entries on the diagonal in the table indicate a growth type group match between the audit and the inventory.

A K statistic was used to compare the observed level of agreement (the proportion of growth type group matches) with the expected level of agreement. The calculated Z-value for the K statistic was 4.526. Since this is greater than the critical Z-value of 1.645 (at a 5% significance level), the K statistic indicates a high level of agreement between

the inventory growth type group classification and the audit classification. As was indicated for the mature inventory classification, these results should be viewed with care.

Analysis of non-forest inventory classification

Thirty stands classified as non-forest were assessed for their inventory assignment accuracy. The resulting score was 78%. This was less than the provincial minimum standard of 85%.

Discussion and conclusions

The objective of the inventory audit in the Fraser TSA was to assess the overall accuracy of the current (1960-62 and 1970-74) Ministry of Forests inventory. The mature, immature and non-forest components were tested.

The results of the initial audit for the mature forested component of the inventory suggest that the inventory may overestimate volume. When the data is post-stratified it becomes apparent that the bias is largely in the operable forested area of the Fraser TSA.

To confirm these findings, an additional 100 samples were taken in the operable forested area. The combined samples were analyzed and indicate that the inventory overestimates volume in the operable forested area.

The results from this inventory audit have been forwarded to the Ministry of Forests Timber Supply Branch for their consideration in the upcoming timber supply analysis for the Fraser TSA. It should be noted that the Fraser TSA is currently undergoing a reinventory, the standards for which will be consistent with the new Vegetation Resources Inventory.

Audit results for the immature component of the inventory suggest an acceptable level of accuracy for site index assignment in young stands.

Although not within provincial standards, the differences found in the assessment of the non-forest classification in this TSA are considered to be minor. The majority of the differences are due to minor changes in classification standards that were not reflected on the existing maps. All major classification criteria were correct.

This study has undergone an external review by Dr. Don Munro, formerly of the UBC Faculty of Forestry, now in private consultancy. Dr. Munro concluded that the statistical audit execution and compilation were consistent with generally accepted timber inventory and statistical estimation principles, and that the audit fairly presents the final average volumes.

References

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Appendices

A Data for the Mature Samples in the Operable Forested Area

B Species Composition by Growth Type Group

C Immature Sample Data

A Data for the Mature Samples in the Operable Forested Area

B Species Composition by Growth Type Group

Growth Type Group Letter Code	Growth Type Group Species Composition
A	pure F
B	FC and FCy, FH, FS
C	FPl, FPy, F Decid., Py, Pa
D	FL, Pw, LF, L
E	C, CF, CH
F	H (and HPl), H Decid.
G	HF, HC, HB, HS
H	B, BH, BS
I	pure S
J	SF, SH (and SC), SB
K	SPl, S Decid.
L	pure Pl
M	Pl F,
N	Pl Decid.
O	D Conif., A Conif.
P	D Decid., Mb, Bi, A Decid.
Q	Cot. Conif., Cot. Decid.

C Immature Sample Data

Glossary

accuracy: A measure of the closeness of an estimate to the true value.

allowable annual cut: The rate of timber harvesting specified for an area of land.

analysis unit: The basic building block around which inventory data and other information are assembled for use in forest planning models. Analysis units represent the general level of aggregation, or detail, at which a timber supply analysis is carried out. They are normally defined by tree species and site qualities.

bias: The quality of a measurement device or procedures that tends to result in a systematic misrepresentation of what is being measured.

coefficient of variation: A relative measure of the variation of the population calculated as the ratio between the standard deviation and the mean value.

confidence interval: The range of values within which the population parameter is expected to lie.

confidence level: The stated probability that a population parameter lies within a given confidence interval.

correlation coefficient: A measure of the linear relationship between two variables. A value of 0 for the correlation coefficient indicates a random relationship whereas a value of ±1 indicates a perfect positive or negative linear correspondence.

diameter at breast height (dbh): The stem diameter (outside-bark) of a tree measured at breast height (1.3 metres above the point of germination) to the nearest millimetre.

field visitations: Ground level field procedures designed to provide physical verification of polygon inventory attributes.

free growing (crop): A crop of healthy trees of a commercially valuable species, the growth of which is not impeded by competition from plants, shrubs or other trees.

inoperable: Refers to areas having merchantable timber that cannot be harvested economically using current harvesting technology because of some physical barrier (such as a hanging valley), and to areas containing small patches of overmature timber surrounded by large areas of young stands.

K statistic: A test for statistical significance of agreement between nominal scale data. The K statistic is calculated as *(actual accuracy - expected accuracy) / (1-expected accuracy)*. The actual accuracy is estimated from the diagonal totals, and expected accuracy is estimated from the marginal totals, from the matrix of similarity (eg. a matrix of audit and inventory GTGs). The value of K is 1 when all elements are on the diagonal (i.e. perfect agreement), and less than 1 otherwise.

mean: The average value of a set of observations.

p-value: The probability associated with the result of a statistical test (eg. test of significant difference). The p-value represents the level of significance for the test; the smaller the value of this probability, the heavier the weight of the sample evidence.

pre-inventory assessments: Pre-inventory analyses are inventory activities to evaluate the existing forest inventory as the basis for deciding whether to re-inventory or update the current inventory, and to document the existing inventory, maps, and photos to support the execution of the reinventory or update if required.

ratio estimate: The ratio between two different estimates.

representative: The quality of a sample having the same characteristics as the population from which it is selected.

sampling: The process of selecting observations from a population.

sampling error: The error attributed to sampling procedures. It is computed as the standard error of an estimate multiplied by a value from the t distribution corresponding to a stated confidence level. Sampling error is often expressed as a percentage of the estimate (eg. percentage of the mean).

significant difference: An expression used in reference to the results of a statistical test in which either two or more estimates are compared or an estimate is compared to a fixed value. If the observed difference is greater than what might be expected as a chance occurrence due to the sampling procedures, the difference is said to be statistically significant.

site index: A measure of site productivity. Site indices are based on tree height as a function of stand age and are usually expressed graphically as site index curves. A number of site index curves have been developed for British Columbia's major commercial tree species.

standard error: An expression of the absolute variability of an estimate. It is computed as the standard deviation divided by the square root of the number of samples.

standard deviation: A measure of the absolute variation of the population.

timber supply analysis: The technical process of amalgamating land management information into computer systems that predict the amount of timber available for harvest over given time periods.

timber supply area: An integrated resource management unit established in accordance with section 6 of the *Forest Act*.

tree farm license: An integrated resource management unit established in accordance with section 28 of the *Forest Act*.